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A Noise Generator with Defined Noise Power for Applications up in the Microwave Range

In recent years, several constructional articles have been published for noise generators (1), (2), (3), for a noise measuring system (4), as well as information regarding this measuring technology (5), (6).

The semiconductor noise generators described in (1) and (2) use the base-emitter diode of an RF-transistor operated in the backward direction. The avalanche effect required for wideband noise is not very prevalent due to the low breakdown voltages of the RF-transistors BFR 34a and BFR 96 of < 5 V. It is mainly a tunnel effect that appears here, which means that the noise spectrum drops off considerably towards higher frequencies (> 1 GHz), (7).

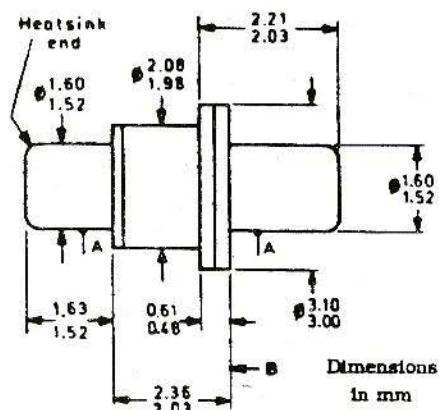
The described noise generator operates with a silicon avalanche diode type BAT 31 which provides a wideband noise spectrum from < 10 Hz to > 18 GHz with a typical noise power (ENR = Excess Noise Ratio) of > 34 dB. This allows manual or automatic noise measurements to be made up to the satellite TV-band of 12.4 GHz with sufficient accuracy even for radio amateurs.

The following article describes the construction of the source and provides technical specifications of the noise diode, as well as describing the construction of a power supply with switching amplifier for

connection to an automatic noise measuring system, and gives further information regarding operational experience.

1. NOISE DIODE

The noise diode used is a BAT 31, which is manufactured by Philips/Mullard in a microwave case type SO 86 (Figure 1). This case is



A = concentricity tolerance ± 0.13

Fig. 1: Case and dimensions of the noise diode BAT 31

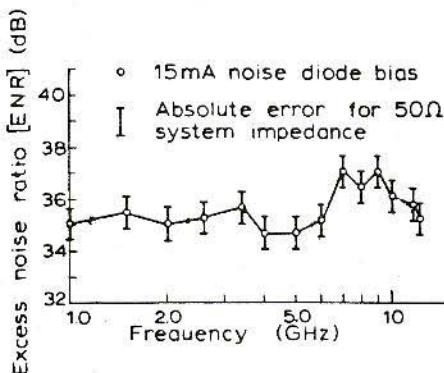


Fig. 2:
Noise power as a function of frequency when installed in a 50Ω system

known from the varactor and Gunn diode technology.

The noise power as a function of frequency in a 50Ω system is shown in **Figure 2**. The fluctuations of the ENR in the amateur bands in excess of 1 GHz amount to ± 0.5 dB, which corresponds to an absolute value of 1 dB when referred to a noise power of 35 dB; this is

a very low value with respect to the large frequency range.

Figure 3 gives the ENR as a function of diode current, and of the frequency. One will see clearly that a current of 13–17 mA is required for wideband operation. The breakdown voltage is between 17 and 22 V.

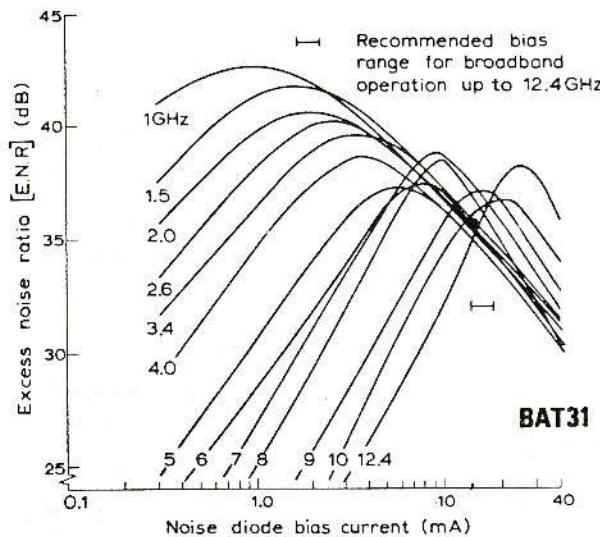


Fig. 3:
Noise power as a function of avalanche current with frequency as parameter when installed in a 50Ω system

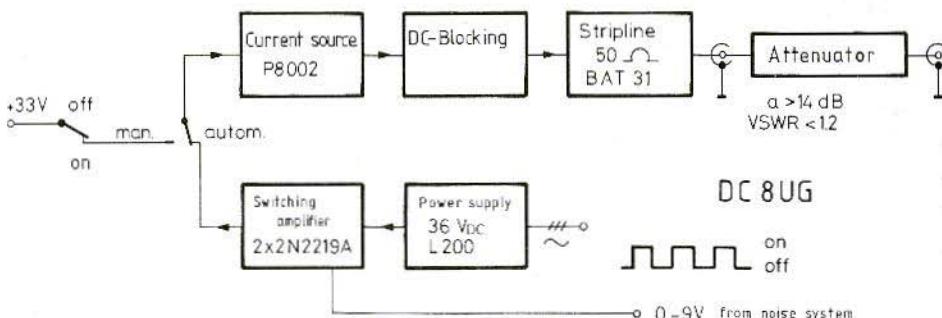


Fig. 4: Block diagram of the noise source and its power supply with switching amplifier

2. CIRCUIT

When used as noise source in switched operation (manual or automatic), the component should exhibit a source impedance of $50\ \Omega$ at all times.

In order to obtain this, the diode is built into a $50\ \Omega$ coaxial or stripline system and terminated with a wideband attenuator of > 14 dB, $VSWR < 1.2$ (see Figure 4). The value of the return loss has a decisive effect on the quality of the measurement (see Section 5). In this circuit, it is exclusively determined by the attenuator. A value of 20 dB with a $VSWR \leq 1.15$ up to 4 GHz and $VSWR \leq 1.25$ from 4 – 12.4 GHz has been found to be sufficiently good (Weinschel, HP, Radiall, or Greenpar). Home-made attenuators are not recommended here! With an attenuation of 20 dB, the ENR will amount to approximately 15 dB and its frequency-dependent fluctuations will now be determined by the diode and attenuator. Good coaxial attenuators have a tolerance of ± 0.5 dB.

Most noise measuring systems are calibrated for use with an Excess Noise Ratio ENR of 15.2 dB. This means that the source is virtually compatible.

In the author's prototype, the diode operates in a $50\ \Omega$ stripline system as shown in Figures 5 and 7. The switch or operating voltage is fed

to the stripline via three, series-connected $150\ \Omega$ metal-film chip resistors. The position, dimensions, and quality of the resistors have an effect on the wideband characteristics of the decoupling.

The diode current is adjusted with the aid of a FET-constant current source, which determines the noise power. Two parallel-connected ATC-100 chip capacitors decouple the swit-

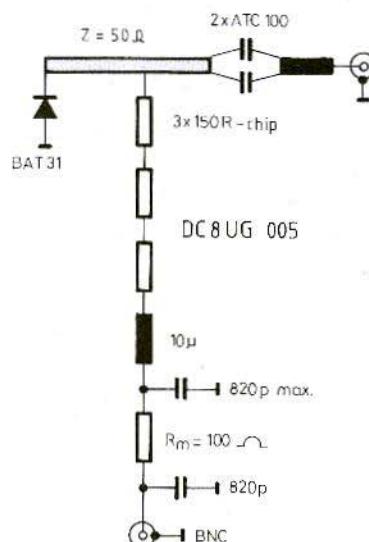


Fig. 5: $50\ \Omega$ stripline system with DC-voltage blocking at the output connector, and wideband choke in the supply line

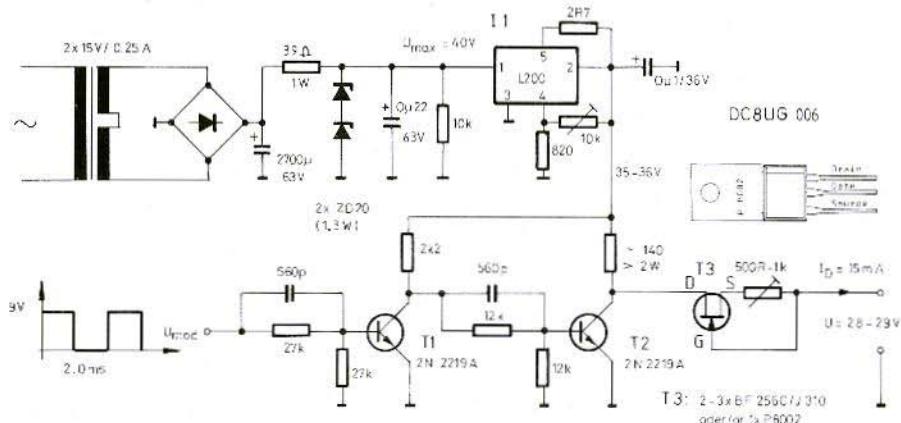


Fig. 6: Power supply with switching amplifier and current source

ching voltage from the attenuator. The switching voltage should amount to at least 33 V, which is generated most favorably using a separate power supply. Figure 6 shows the circuit diagram of the power supply with switching amplifier and current source. If the amplifier input is provided with a modulator pulse of, for instance, 9 V, 500 Hz squarewave-voltage, a current and voltage-controllable pulse of the same frequency and sufficient power will be available at the output. This allows the source to be used together with the

noise figure measuring system described in (4), or with older noise figure measuring systems (eg. the GM 551 A).

3. CONSTRUCTION

The diode system comprises mainly a double-coated, PTFE-board (RT-duroid 0.79 mm) onto which a 50Ω line has been provided. The coupling of the diode to the line must be made extremely accurately, since it determines the value of the available noise power at the upper frequency limit.

Further details regarding this are given in Figure 8. The diode mount comprises a gold-plated M4-screw with which the diode is coupled to the stripline on the ground-side of the board via a M4-nut. In order to achieve this, the line is provided with a 1.5 mm hole at the end, which is carefully extended to 2 mm diameter. The central position of the nut is guaranteed by use of a dummy instead of the noise diode (such as a defective varactor or Gunn diode). After this, a small gold plate is prepared with a width of 2.3 mm, length approx. 3 mm, and a 1.6 mm hole, and is placed over the dummy and soldered to the

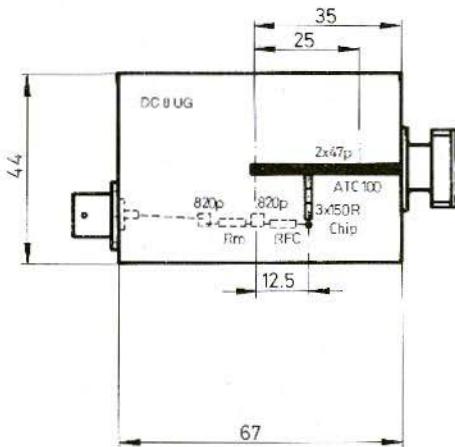


Fig. 7: Layout of a 0.79 mm RT/duroid board

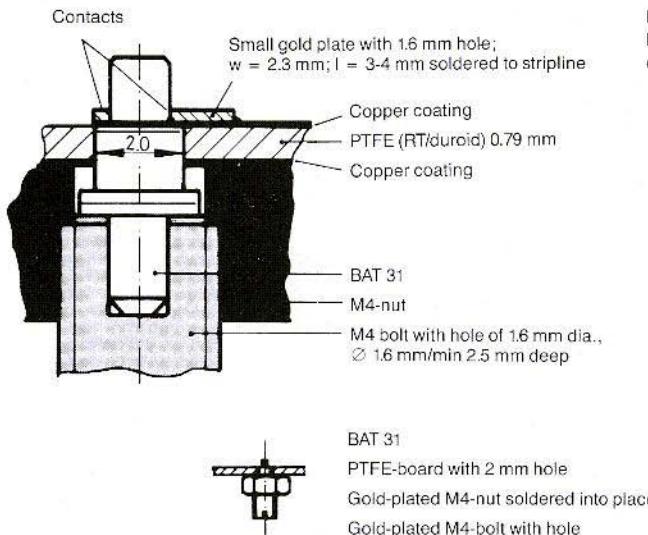


Fig. 8:
Installation details
of the noise diode

stripline. The small gold plate can be obtained from a connection strip of a power transistor. The dummy is now removed, and the hole is widened from the rear side through the M4-nut with the aid of a 2.1 mm drill, so that one can guarantee that the diode is coupled to the stripline with the aid of the lower cathode connection via the gold plate. With a careful construction, one will achieve a good stripline-coaxial transition.

After this, the PC-board is soldered into a metal box. The DC-switching voltage is now fed in via a BNC-connector, and the stripline should be terminated with the lowest discontinuity with an SMA or N-connector (preferably N-plug). One should only use precision N-connectors (clean thread, gold pin, maybe using a small flange). If one expects to obtain reproducible measuring results, it is important that no movable coaxial connections are provided. For this reason, BNC should not be used!

Finally, the chip capacitors, chip resistors, and the choke with the precision resistor, and the two disk capacitors on the ground side, are installed.

On inserting the diode, check for correct pola-

rity (blocked operation) using an Ω -meter. **Figure 9** shows the author's prototype from both sides.

The power supply with switching amplifier and constant current source can be accommodated on the epoxy PC-board shown in **Figure 10**. If manual operation is to be used exclusively, one will not require the switching amplifier, which means it can be deleted from the board.

4. OPERATION

Check the power supply before connecting it to the noise source. This is achieved by replacing the noise diode by a 20 V zener diode and connecting it via a dropper resistor of 470Ω to the power supply. At an output voltage of 36 V from the stabilizer L 200, it should be possible to adjust a current of 15 mA with the aid of the trimmer potentiometer of the current source. CAUTION: T 2 must block!

Furthermore, the switching amplifier should be driven with the modulator pulse from the noise measuring system, and the waveform at

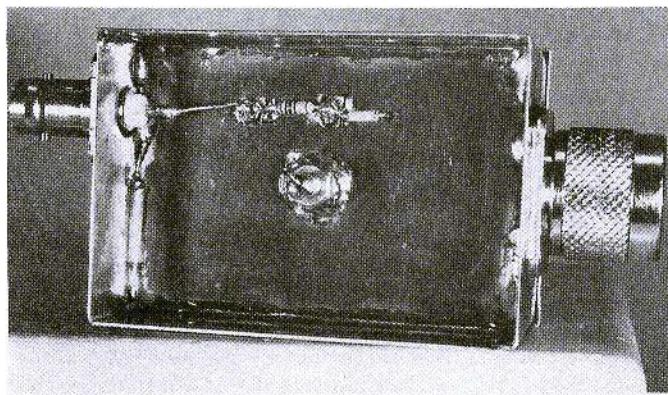
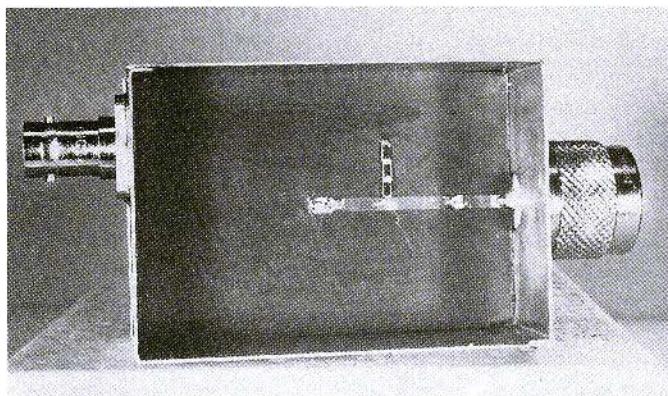


Fig. 9:
On the upper side of the noise source (without attenuator), one will see the blocking capacitors, the three chip resistors, and the built-in diode. On the lower side, one can see the diode mount and the precision resistor soldered into place between the two disk capacitors.

the output checked with the aid of an oscilloscope.

If everything is working correctly, the source can be connected to the power supply. The current value should be aligned using the trimmer of the current source. This can be checked by measuring the voltage drop across the precision resistor $R_m = 100 \Omega$. Preliminary, it is sufficient to adjust the current to $15 \text{ mA} \pm 1.5 \text{ V}$ voltage drop. In the case of a pulsed diode, one can measure this best with the aid of a RMS-voltmeter, or oscilloscope.

For relative noise measurements, or comparison measurements for optimizing the receive sensitivity of amplifiers etc., it is not necessary for the ENR to be calibrated exactly. However, for absolute measurements, it is absolutely

necessary for the source and attenuator to be compared to a calibrated noise source over the whole frequency range of interest.

5. OPERATIONAL EXPERIENCE

The author has been using a BAT 31-noise source with great success for more than three years. It was firstly used in manual operation for measuring the Y-factor, and later used in conjunction with a noise measuring system, type 551 A, manufactured by General Microwave.

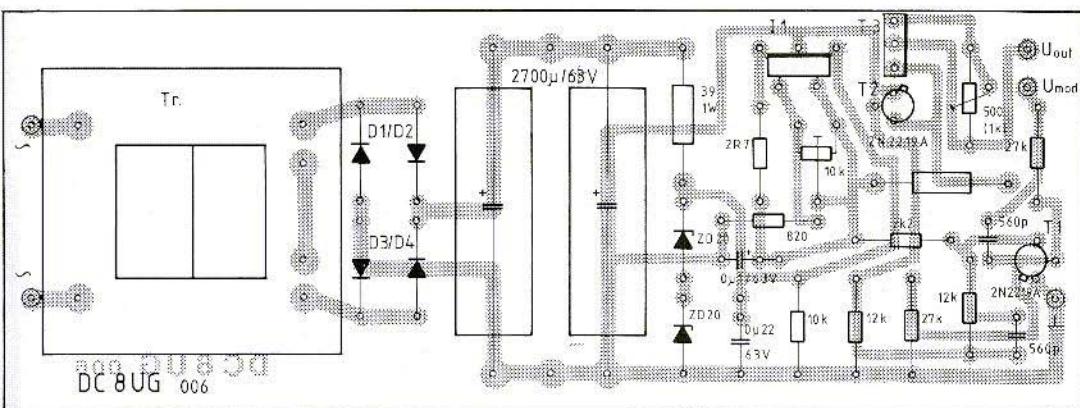


Fig. 10: Component locations on the power supply/switching amplifier board DC 8 UG 006

For absolute measurements, it is necessary to know the ENR for the amateur radio bands. Comparisons to AIL-noise systems using HP-

sources showed that the source described here, used in conjunction with a 20 dB attenuator, exhibited the following ENR-values:

144	432	1296	2320	3456	5760	10368 MHz
15.8	15.4	15.2	15.2	15.0	16.9	14.0 dB

Sufficient noise power is also available in the shortwave range. It is even possible to carry out alignment for maximum sensitivity in the 80 m band. However, exact noise power values were not determined.

The principle of noise measurements is not to be described here, since sufficient articles have been published regarding this subject (1), (2), (6).

However, the author would like to give some information regarding the measuring accuracy, especially in conjunction with automatic noise measuring systems.

Among experts, there is no doubt that all automatic noise measurements have a considerable uncertainty, especially in the range below 3 dB. The following errors are added to the

fluctuations of the source-ENR as a function of frequency:

1. Accuracy of the noise meter
e.g. AIL 7514 \pm 0.15 dB, GM 551 A \pm 0.25 dB, HP 340 A \pm 0.50 dB, all in the lowest range.
2. Temperature error
 \pm 0.1 dB with a \pm 10 degree deviation from 290 Kelvin
3. Image noise power
up to $+ 3$ dB, this can be avoided by using suitable circuitry.
4. Mismatch source – test object
This error is not considered carefully enough during noise measurements in the range below 3 dB. For this reason, **Figure 11** shows this effect graphically.

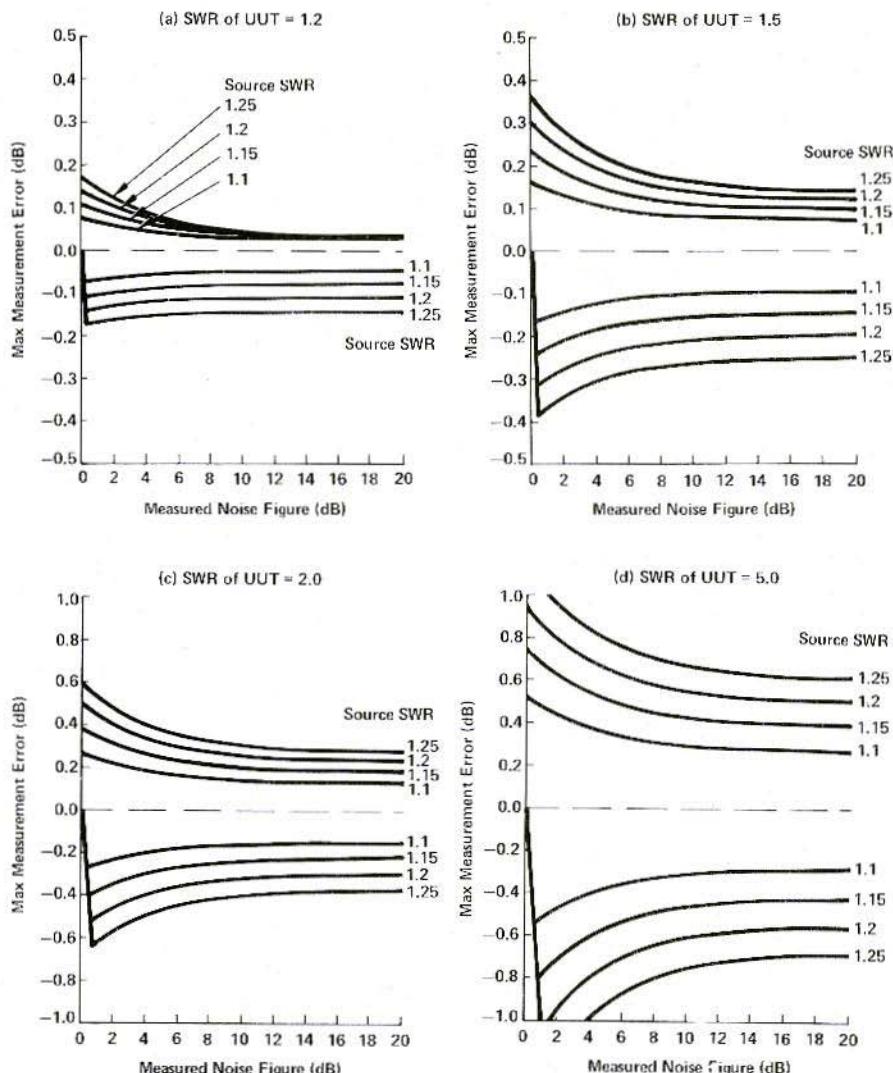


Fig. 11: Maximum measuring error as a function of the measured noise figure, as well as of the VSWR-values of the noise source and test object (UUT, Hewlett-Packard).

Example: In the case of a determined noise figure of 2 dB, a source-VSWR of 1.2, and a test object-VSWR of 2.0, the measuring uncertainty will be in the order of ± 0.5 dB!

As can be seen further, the return loss of

the noise source cannot be large enough in order to provide tolerable measurements in the range below 2 dB, especially when the test objects possess a high standing wave ratio.



If these errors are added in the correct sign, one will arrive in a tolerance range that makes the decimal dB-values seem ridiculous. Even if one assumes that those can appear with opposite signs, and the actual accuracy of the measuring system is greater than the tolerance value, one should note that differences of 0.5 dB must be accepted, when using the same preamplifier at different times with different measuring set-ups on the same measuring system.

This just is to demonstrate how questionable most noise figure values under 1 dB are if they are not measured using an exactly calibrated hot/cold standard, but have been automatically measured, and that tenths-of-a-dB-values can be ignored.

To summarize, it can be said that the possibility of comparison measurements in the SHF-range represents an important aid for the home constructor and critical amateur consumer, especially considering the increasing activity. Absolute values should be of second importance to radio amateurs, since the optimization of every receive system must be made including the antenna, and this is achieved best using solar noise (8).

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